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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
G08B 23/00, 1/08, 21/00, A61B 5/103, H01H 35/02

A1

(11) International Publication Number: WO 96/36950

(43) International Publication Date: 21 November 1996 (21.11.96)

(21) International Application Number: PCT/US96/02976

(22) International Filing Date: 2 February 1996 (02.02.96)

(30) Priority Data:
08/443,911 18 May 1995 (18.05.95) US
60/000,970 7 July 1995 (07.07.95) US

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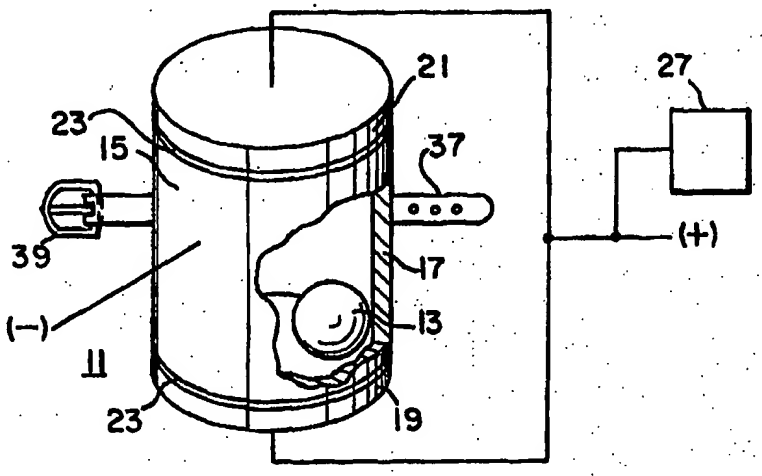
(81) Designated States: AT, AU, CA, CH, CN, DE, DK, ES, FI, GB, JP, KR, LU, MX, NO, PT, SE, SG, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: MOTION SENSOR

(57) Abstract

A patient movement monitoring device including a sensor (11) for generating motion signals, a signal edge detector, an integrator (A-B), a threshold detector for generating an alarm signal, and preferably a radio transmitter for relaying the alarm signal. The sensor is in the form of an intermittent switch comprising a conductive rolling sphere (13) in a cylindrical chamber (15) having a conductive wall (17) as one electrical pole and end plates (19, 21) electrically insulated from the conductive wall and forming the other electrical pole such that movement of the device will generate intermittent electrical contacts between an end plate and the cylinder wall.



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MOTION SENSOR

The invention described herein may be made, used or licensed by or for the U.S. Government for Governmental purposes.

FIELD OF INVENTION

The present invention relates to a monitoring device for sleeping individuals. More particularly, the present invention relates to a motion sensor which detects a particular type of motion over a preselected period of time to then trigger an alarm.

BACKGROUND OF INVENTION

Epilepsy is a disorder of the brain characterized by recurring seizures, in which there are uncontrolled electrical discharges of brain cells. Epilepsy may arise from a very small area of damaged brain tissue, or from the entire brain. There may be no apparent brain damage, or damage may be limited to an area so small it cannot be detected. Therefore, in nearly one-half of the cases, the cause of epilepsy is unknown.

There are several types of seizures associated with epilepsy, the most common of which are generalized tonicclonic (grand mal), absence (petit mal), complex partial (psychomotor), and elementary partial (focal motor). Each seizure type can be characterized by various symptoms. However, the seizures are generally not life threatening, lasting at most up to three minutes. The exception is *status epilepticus*, also called continuous seizure state. This is the occurrence of repetitive or continuous seizures and affects approximately 3 to 5% of those individuals suffering from epilepsy. It can exist with all types of seizures and may result in irreversible brain damage or death

without prompt medical attention.

One of the specific problems encountered by parents having children afflicted with epilepsy, particularly *status epilepticus*, is the problem of alerting the parents when the child may be having an epileptic seizure during sleeping hours. To date the only recourse the parents have is to sleep with the child, in the same bed, hoping to be awakened by the seizure during its early stages when the seizure motion may be quite mild. Often, the parents will choose to supplement this safeguard by using an alarm clock, set to sound every hour, to awaken and observe the state of the child. This, of course, places an extraordinary burden on both the child and the parents and is inherently unreliable. The intermittent sleep afforded the parents as well as the desire for privacy by the child and by the parents make the procedure impractical and inefficient.

Motion sensor devices are obvious solutions to the aforementioned problem, provided that such devices can be designed to ignore the casual motions of a sleeping child (rolling over, etc.) while responding to those motions characteristic of a seizure, however mild at the beginning. Existing motion sensor devices such as accelerometers or displacement followers could conceivably be designed to detect certain types of motion while ignoring others, but are invariably expensive and, when the required signal conditioning equipment is included, form a bulky package. Moreover, these devices commonly require electrical connections between the transducer (affixed to the patient) and its associated equipment located near, but not on, the patient.

Accordingly, it is an object of this invention to provide a device for sensing the motion of concern while ignoring, for the most part, other non-harmful motion such as ordinary movement during sleep.

Yet another object of this invention is to provide a simple, effective device for monitoring epileptics without disturbing the

sleep of the patient or the observer unless there is a need for concern.

Other objects will appear hereinafter.

SUMMARY OF THE INVENTION

It has now been discovered that the above and other objects of the present invention may be accomplished in the following manner. Specifically, the invention comprises a motion detection device for use as a monitor for patient movement.

The device includes a sensor means suitable to be attached to the patient for generating motion signals in response to movement of the sensor means. The sensor means includes an intermittent switch means for generating a series of sharp voltage rises and falls to generate a sequence of voltage pulses of predetermined magnitude and time duration. Preferably the sensor means includes edge detector means for providing a motion sensed output. The edge-detector means includes a pair of coupled NOR gates and a non-retriggerable monostable multivibrator to condition the motion signals to match the condition of the switch means.

The integrating means is adapted to integrate the motion signals over a period of time. Part of the integrating means is a threshold means for generating an alarm signal when a predetermined minimum value of the motion signal is exceeded. An intermittent switch is provided for responding to the alarm signal and activating an alarm. A transmitter produces a transmitted radio signal upon receipt of the alarm signal. The radio signal is receivable by a conventional radio.

The integrating means includes a voltage leakage circuit for defining the minimum amount of movement needed to generate the alarm signal. The device further includes reset means for bringing the device to an at-rest condition. The device also includes means for adjusting the sensitivity of the threshold means.

The preferred intermittent switch comprises a conductive

rolling sphere in a cylindrical chamber having a conductive wall with one electrical pole. End plates are electrically insulated from the conductive wall and from the other electrical pole so that movement of the sphere caused by movement of the cylinder will generate intermittent electrical contact between one end plate and the cylinder wall. This cylinder is easily attached to a patient for monitoring.

The present invention offers an extremely simple, lightweight and inexpensive means for detecting motion. Since the problem of the present invention is solved by detecting or sensing motion, there is no need to measure the motion in detail, beyond detecting it. Devices which so measure motion involve considerable technical and cost overkill without adding anything to the desired objects and goals in this particular invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the invention, reference is hereby made to the drawings, in which:

FIGURE 1 is a schematic view illustrating the sensor of this invention, shown in perspective with parts broken away for clarity, with means shown for attachment to a patient.

FIGURE 2 (comprised of Figures 2A, 2B and 2C) shows a circuit diagram of the present invention illustrating the preferred embodiment as it is designed for use with an epileptic child needing overnight motion supervision. Figure 2A section shows an edge detector stage which feeds into Figure 2B summing integrator to close a latch stage, which in turn sersves to activate an alarm stage in Figure 2C.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in Figure 1, the sensor 11 is a simple design in which a conductive rolling element or sphere 13 is placed in a conductive cylindrical chamber 15 having a conductive wall 17 with one electrical pole, shown in Figure 1 as the negative pole. End plates 19 and 21 are electrically insulated by insulating

layer 23 from the conductive wall 17 and both constitute the other electrical pole, here positive as shown in Figure 1, such that movement of sphere 13 caused by movement of the cylinder will generate intermittent electrical contact between one end plate 19 or 21, for example, and the cylinder wall 17. Wrist watch strap 37 with an adjustable fastening device such as buckle 39 or, alternatively, a Velcro fastener or clasp (not shown) allows attachment of the sensor or the entire monitor to the patient on the wrist, ankle, arm or leg, for instance, as may be desired. It may also be worn as a belt, e.g., depending upon particular size and comfort needs of the patient.

The sensor 11 effectively operates as a "jiggle" switch as the small, electrically conductive sphere 13 is able to move freely inside the small hollow cylinder 15. Wall 17 is conductive as are end plates 19 and 21, each of which are separated from wall 17 by an insulator 23. The end plates 19 and 21 are electrically connected and form one pole of the switch.

When sphere 13 is in contact with either end plate 19 or 21 and with the cylinder wall 17, the switch is electrically closed through such mechanical positioning, hereafter referred to as mechanically closed. Depending on the presence of oxides and/or surface roughness, the contract resistance may be quite high and the switch may or may not be electrically closed. The important feature is that even small motions of the switch cause the ball 13 to roll. Because this mechanically closed switch position is the only stable position for the ball 13 in cylinder 15, i.e., in contact with wall 17 and an end plate 19 or 21, most of the rolling takes place in this configuration. Ideally the inside cylinder walls, and the inward sides of the end plates, are made to arch inward in some fashion to insure the ball can only roll in said configuration in contact with both the cylinder and with one of the end plates. As ball 13 rolls, electrical contact with wall 17 is intermittent, owing to the previously mentioned variations in contact resistance. On an oscilloscope, the voltage measured between the positive and negative poles which

are shown in Figure 1 appear as a sequence of sharp rises and falls, and in turn can be used to generate a sequence of rectangular voltage pulses pre-designed in magnitude and time duration. These pulses can then be integrated over time. If motion does not continue, the voltage can be arranged to be dissipated by leakage which effectively prevents the integral from reaching a value that will activate an alarm. If motion persists, however, a tiny radio transmitter in the electronic circuit means (Figure 2) can be activated by sending a signal tone to a common household radio receiver located nearby.

As shown in Figure 2, the electronic circuit means functions with a very small number of discrete components, operating from a single 3 volt DC watch battery. The circuit shown in Figure 2 is designed with the limitations of power and size dictated by its intended place of use. Thus, all active components are low power CMOS devices of FETs.

The circuit shown in Figure 2 can be divided into four primary functions. These are: an edge detector and signal conditioner (Figure 2A), an integrator with a latch (Figure 2B), and an alarm mechanism (Figure 2C); S2 represents element 11 of Figure 1, whereas switch S1 represents merely a power-on switch. The edge detector is able to detect a sudden rise, or a sudden fall, in the voltage level (the "spikes"). Either change tends to indicate a motion made by the patient. In response to the above detections, of either an up or down-going spike, the conditioner circuit will generate positive going pulses, all of equal height (amplitude) and of equal width, regardless of the spike's polarity, amplitude, or (short) duration. The count of the number of square pulses is an indication of the number of motions that were made. If motion changes occur during the period of one of these pulses, such changes will not be acted upon.

The edge detector comprises two coupled NOR gates 1a and 1b as shown in Figure 2, because the state of switch 11 when it is at rest is not known, nor can it be known if it is to operate

over universal conditions. A non-retriggerable monostable multivibrator 2a conditions the signal produced by the edge detector to match the characteristics of switch 11 to the motions of interest. As has been noted, the switch 11 and the circuit of Figure 2 ensure that the system will be less sensitive to large motions than it is to the smaller vibrations associated with "hard shiver" epilepsy seizures.

The output of the monostable multivibrator 2a at A is fed to an integrator A - B, where the pulses are summed and trigger a latch (shown by the remaining NOR gates 1c and 1d) if the CMOS logic threshold is exceeded. Note also that the control voltage continuously decays through a bleeder resistor (4.7M) and will eventually drop to zero at Vss when the system is at rest.

The output B of the latch enables an astable multivibrator designed from the second monostable multivibrator 2b. The output of this astable multivibrator 2b is designed to pulse a VMOS power FET and permit a 3 volt battery to operate a transmitter DECO VT-75 at controlled bursts of relatively high current drain. The frequency of oscillation used as an input to the transmitter is derived from a 555 low power timer 3 configured to oscillate at about 600 Hz. The 555 is also enabled by the VMOS power FET. Pulsing both the transmitter and 555 minimize current drain and limit standby current to about 4 micro amps.

As shown in Figure 1, the motion sensor of the present invention is designed for attachment to a person who is susceptible to epileptic seizures, particularly of the forms of epilepsy which are life threatening, such as those which may be characterized by a "hard shiver". The watch strap in Figure 1 is a means for attaching the sensor or the entire monitor to the patient, on a wrist, or, for example, on a leg. In some cases the monitor may be worn as a belt. A buckle is shown in Figure 1, but other attachment means can be used such as Velcro fasteners and the like.

The procedure to use the sensor includes the following steps. the sensor is shaken sufficiently to trigger the radio

alarm. The radio is tuned until the alarm tone is heard. The reset switches S3 and S4 are then momentarily closed on the sensor, stopping the alarm. The sensitivity of the sensor is then adjusted so that the alarm sounds in response to motion that has persisted for a length of time determined by the operator, usually the parent. The reset switch is again closed momentarily and the sensor is now in its ready to use state.

In applying the motion sensor to an epileptic child, it is desirable that occasional movement, not indicative of a seizure, not trigger the alarm. The sensor sensitivity effectively selects a time period during which motion must be quasi--continuous for the alarm to be triggered. In addition, the switch design is such that it is more sensitive to small motions than to large motions since the rolling sphere breaks contact with either the end plate or the cylindrical wall with virtually every small movement of the sensor. Of course, the sensitivity can be adjusted or set at various settings depending upon the degree of sensitivity needed and the particular application of interest. When the motion sensor is applied to situations in which any or all motion is of interest, the sensitivity can be set at the maximum setting. The device may also be useful for monitoring brain injured persons in a health care facility, it is suggested.

While particular embodiments of the present invention have been illustrated and described herein, it is not intended that these illustrations and descriptions limit the invention. Changes and modifications may be made herein without departing from the scope and spirit of the following claims.

CLAIMS

1. A motion detection device for use as a monitor for patient movement, comprising:

sensor means for generating motion signals in response to movement of said sensor means, and said sensor means including means for attachment to a patient;

integrating means for integrating said motion signals over a period of time, said integrating means including threshold means for generating an alarm signal upon exceeding a predetermined minimum value of said motion signals; and

switch means for responding to said alarm signal to activate an alarm.

2. The motion detection device of claim 1, wherein the sensor means includes edge detector means for providing a motion sensed output, said edge detector means including a pair of coupled NOR gates and a non-retriggerable monostable multivibrator to condition said motion signals to match the condition of said switch means.

3. The motion detection device of claim 2, wherein said sensor means includes an intermittent switch means for generating a series of sharp voltage rises and falls to generate a sequence of voltage pulses of predetermined magnitude and time duration, and said integrating means includes voltage leakage means for defining the minimum amount of movement needed to generate said alarm signal.

4. The motion detection device of claim 1, wherein said intermittent switch means comprises a conductive rolling element in a cylindrical chamber having a conducting wall with one electrical pole and end plates electrically insulated from said conductive wall and forming the other electrical pole such that movement of said element caused by movement of said cylinder will generate intermittent electrical contact between one end plate and the cylinder wall.

5. The motion detection device of claim 4, wherein said element

is a conductive sphere.

6. The motion detection device of claim 1, wherein said device further includes transmitter means to produce a transmitted radio signal upon receipt of said alarm signal, said radio signal being receivable by a conventional radio.

7. A motion detection device for use as a monitor for patient movement, comprising:

sensor means for generating motion signals in response to movement of said sensor means, said sensor means including edge detector means for providing a motion sensed output, said sensor means also including means for attachment to a patient;

integrating means for integrating said motion signals over a period of time, said integrating means including threshold means for generating an alarm signal upon determining a predetermined minimum value of said motion signals;

switch means for responding to said alarm signal to activate an alarm; and

transmitter means to produce a transmitted radio signal upon receipt of said alarm signal, said radio signal being receivable by a conventional radio.

8. The motion detection device of claim 7, wherein said edge detector means including a pair of coupled NOR gates and a non-retriggerable monostable multivibrator to condition said motion signals to match the condition of said switch means.

9. The motion detection device of claim 7, wherein said sensor means includes an intermittent switch means for generating a series of sharp voltage rises and falls to generate a sequence of voltage pulses of predetermined magnitude and time duration, and said integrating means includes voltage leakage means for defining the minimum amount of movement needed to generate said alarm signal.

10. The motion detection device of claim 7, wherein said intermittent switch means comprises a conductive rolling sphere in a cylindrical chamber having a conductive wall with one electrical pole and end plates electrically insulated from said

conductive wall and having the other electrical pole such that movement of said element caused by movement of said cylinder will generate intermittent electrical contact between one end plate and the cylinder wall.

11. The motion detection device of claim 7, wherein said device further includes reset means for bringing said device to an at-rest condition.

12. The motion detection device of claim 7, wherein said device includes means for adjusting the sensitivity of said threshold means.

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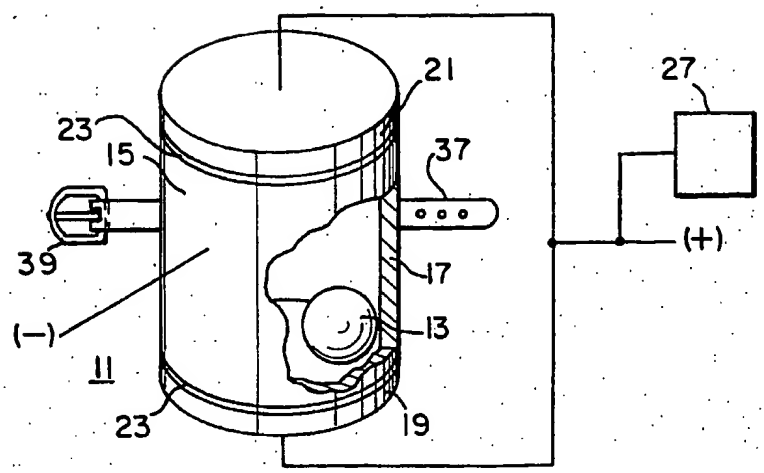
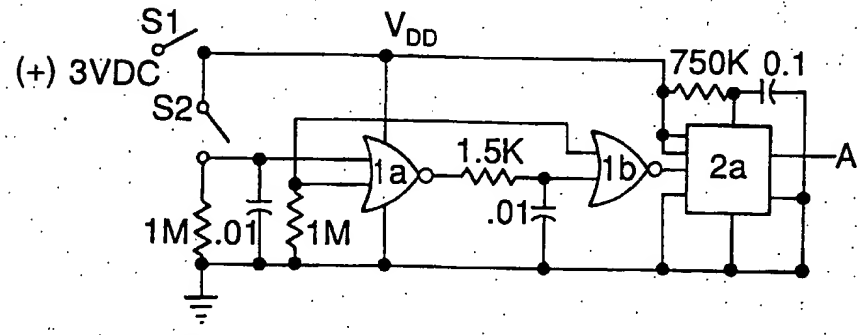
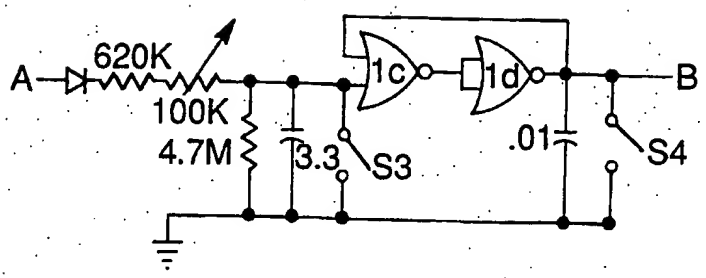


FIG. 1



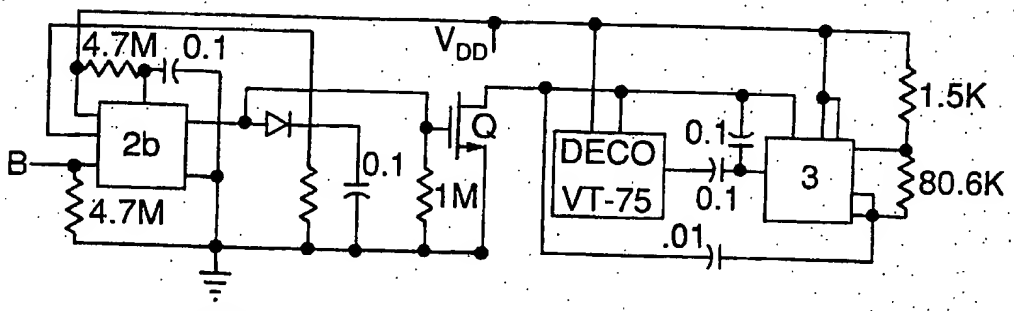
EDGE DETECTOR & CONDITIONER

FIG. 2A



INTEGRATOR & LATCH

FIG.2B



OSCILLATORS &TRANSMITTER

FIG.2C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/02976

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G08B 23/00, 1/08, 21/00; A61B 5/103; H01H 35/02
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 340/526, 529, 539, 573, 686, 687, 689, 693; 128/782; 200/61.45R, 61.52

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,884,067 (NORDHOLM ET AL.) 28 November 1989, figures 1-4 and 6 and related disclosure.	1-3, 5-9 and 11-12
Y	US, A, 3,796,208 (BLOICE) 12 March 1974, col. 6, lines 45-57 and 60-67; col. 7, lines 48-52; col. 8, lines 25-33.	1-3, 5-9 and 11-12
A	US, A, 4,536,755, (HOLZGANG ET AL.) 20 August 1985, Fig. 5 and related disclosure.	1-12.
A	US, A, 4,679,036, (CHENG) 07 July 1987, figures 1-4 and 7-8 and related disclosure.	1-12.
A	US, A, 4,682,155 (SHIRLEY) 21 July 1987, figures 1 and 3 and related disclosure.	1-12.

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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International application No.
PCT/US96/02976

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,322,714 (MORGAN) 30 March 1982, figure 1.	1-12.
A	US, A, 4,747,216 (KELLY ET AL.) 31 May 1988, figures 1-5 and 11 and related disclosure.	1-12.
A	US, A, 4,833,456 (HELLER) 23 May 1989, figures 1 and 3-5 and related disclosure.	1-12.
A	US, A, 4,117,834 (MCPARTLAND ET AL.) 03 October 1978, col. 1, lines 5-54.	1-12.
A	US, A, 4,337,402 (NOWAKOWSKI) 29 June 1982, figures 1 and 5-6 and related disclosure.	1-12.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/02976

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

340/526, 529, 539, 573, 686, 687, 689, 693; 128/782; 200/61.45R, 61.52